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***E-Motion mis-sight* and other temporal processing disorders in autism**

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I- Introduction

We thank Elizabeth Milne, John Swettenham and Ruth Campbell for their review on a new important topic in neuropsychology of autistic spectrum disorders (ASD), i.e., visual-motion processing (Milne et al., 2005). They give us the opportunity to precise several points and to complete our own view on this topic.

As they say, our group was the first to investigate motion perception in autistic children, with a visuo-postural paradigm : this reflex-paradigm was particularly adapted to investigate children with low-functioning autism (LFA), since no verbal or voluntary motor answer were required for exploring basic ‘low level’ - optic flow – processing in these subjects.

These children with LFA that we meet in child day-care psychiatric units force us – clinicians-researchers - not only to understand their neuropsychological impairments, but also to help them here-and-now, and help their bewildered parents (Tardif & Gepner, 2003).

Thus, another difference between clinicians-researchers and researchers is that the former generally try to investigate not only high-functioning autism but also low-functioning autism. Thus, their view on subjects with ASD is not only based on their high-order cognitive peculiarities but also involves their low level perceptual impairments.

II- How was born the idea of visual-motion *mis-sight* in autism ?

Several arguments induced us to suppose that at least some individuals with autism may suffer a visual-motion *mis-sight*, i.e., a visual-motion processing disorder affecting attention to visual-motion, and/or perception of motion, and/or visuo-motor integration of motion.

These arguments come from (1) clinical observations, (2) adult neuropsychology, (3) developmental psychopathology, (4) self-reports from adults with high-functioning autism, and (5) experimental cognitive neuropsychology.

(1) Clinical observations

What fascinates and/or disturbs almost everyone who encounters children with ASD for the first time is the frequent contrast between their physical presence and psychical absence.

When observing them carefully, we discover rapidly that the 'autistic world' they live and move in is obviously different from our world.

Whatever is our grid of interpretation, we promptly come to think that they feel, process and interpret the world differently than we do. People exhibiting so peculiar manners and behaviors cannot be like us.

Sometimes, with some adults having an Asperger syndrome, or with some relatives of first or second degree of individuals with autism, we still feel subtle differences between them and us in facial speech, eye speech, emotional expressions and social contact.

But what exactly is the difference ? Who are autistic persons, how do they (dys)-function ? Since Kanner (1943), this question is still passionately debated. As a matter of fact, Kanner noted in almost all of the eleven children with autism several behavioral peculiarities, that are directly related to *movement* (movement perception or action) and *statics* (details of objects, puzzles), some others possibly being indirect consequences of these impairments (i.e., symptoms having an adaptative or compensatory function), e.g., gaze and face avoidance ; attraction or aversion for moving, spinning and rolling objects ; attraction for details, static forms, puzzles ; motor clumsiness ; manual, gestural and postural stereotypes ... All these symptoms evoke a possible dissociation between a movement vision deficit and a static over-vision (Gepner, 2001).

(2) Adult neuropsychology

Zihl, von Cramon and Mai (1983) reported the case of a woman aged 43 who suffered a bilateral posterior brain damage, which selectively affected her movement vision.

« The visual disorder complained of by the patient was a loss of movement vision in all three dimensions. She had difficulty, for example, in pouring tea or coffee into a cup because the fluid appeared to be frozen, like a glacier. In addition, she could not stop pouring at the right time since she was unable to perceive the movement in the cup when the fluid rose. Furthermore the patient complained of difficulties in following a dialogue because she could not see the movements of the face, and especially the mouth of the speaker. In a room where more than two other people were walking she felt very insecure and unwell, and usually left the room immediately, because 'people were suddenly here or there but I have not seen them moving'. The patient experienced the same problem but to an even more marked extent in crowded streets or places, which she therefore avoided as much as possible. She could not cross the street because of her inability to judge the speed of a car. 'When I'm looking at the car first, it seems far away. But then, when I want to cross the road, suddenly the car is very near'. She gradually learned to 'estimate' the distance of moving vehicles by means of the sound becoming louder » (Zihl et al., 1983, p. 315).

This remarkable case study lets us measure the extremely important impact of a selective disturbance of movement vision affecting a young – previously normal - woman on her perceptual, sensorimotor, communicative and social behaviors. It is then easy to imagine the various developmental consequences of a visual-motion processing disorder affecting a baby from the beginning of his life.

(3) Developmental psychopathology

Since two decades, several studies using family home movies identified a number of very early specific signs of autism in babies aged 0 to 24 months, in various aspects of development, i.e. perception (vision, audition, proprioception) and sensorimotor development, in verbal and non verbal communication and in socialization (Sauvage, 1988). Here, we describe early signs of autism that can be related to a possible visual-motion perception and/or visuo-motor integration deficit. Note that these early signs are sometimes very subtle, and that they are not systematically observed in babies who will present later an autistic syndrome (e.g. disintegrative syndrome).

In the first weeks of life, autistic babies may exhibit anomalies of gaze contact and ocular pursuit of moving objects or persons. Around 3 months of life, autistic babies show a deficit in attention to familiar persons, and poor facial expressions. Around 6 months, visual contact disorders may persist, with « empty gaze », squint, impression of blindness. At the same time, babies may exhibit atypical interests for their hands, details of objects, static forms, and a lack of interest for moving games or forms. Between 6 and 12 months of life, autistic babies may show a deficit of imitation of facial expressions, a lack of interest for people ; they withdraw from social interaction ; simultaneously, they exhibit new self-stimulating sensory and sensorimotor behaviors, like fingers and hand flapping in front of their eyes. In the second year, autistic infants may show a lack of visual attention (peripheral gaze) and joint attention, and peculiar interests for light sources, reflected light, shadows, wind in trees...(Sauvage, 1988).

As far as motor development is concerned, autistic babies may show disturbances in some or all of the milestones of development, including lying, righting, sitting, crawling and walking (Teitelbaum et al., 1998). Besides, they frequently exhibit postural adjustments disorders, and a lack or a delay in anticipating attitudes, as well as oculo-manual coordination disorders, lack of environment exploration, and stereotyped behaviors like swinging, rocking, swaying (Sauvage, 1988 ; Leary and Hill, 1996 for a review).

To summarize, the first signs of autism concern with visual development, with a dissociation between static vision (normal or even overdeveloped, with attraction for details, as also found later in children and adults with HFA and Asperger syndrome, see Frith, 1989 ; Happé, 1999 ; Mottron, 2004) and movement vision (poor, deficient, aversive). Secondly, while autistic babies may show a developmental delay (that we could name 'negative signs of autism'), they also show atypical self-stimulating visual and visuomotor behaviors, i.e., a developmental deviant trajectory (that we could name 'productive signs of autism'), some of which probably have an adaptative and/or compensatory value. Third, it is possible to consider the progression of autistic symptomatology over time as a succession of *mis-developmental cascades*, in which impaired visual behaviors will secondarily impair visual, but also visuo-motor, communicative and social interactions between autistic child and his human and physical environment (Gepner, 2001, 2004 & 2005 ; see also Figure 1). Finally, in this description of early autistic signs are missing all the elements related to audition, which also contribute to language developmental disorders in autism. We will consider these elements below.

(4) Self-reports from adults with autism

Some adults with high-functioning autism gave us important testimonies on their inner world, some of which are directly related to movement, speed of changes, and compensatory strategies.

Donna Williams wrote : « The constant change of most things never seemed to give me any chance to prepare myself for them. Because of this I found pleasure and comfort in doing the same things over and over again. I always loved the saying, 'Stop the world, I want to get off'. Perhaps I'd been caught up in the spots and the stars at a time when other children kept developing and so I had been left behind. The stress of trying to catch up and keep up often became too much, and I found myself trying to slow everything down and take some time out... One of the ways of making things seem to slow down was to blink or to turn the lights on and off really fast. If you blinked really fast, people behaved like in old frame-by-frame movies, like the effect of strobe lights without the control being taken out of your hands» (Williams, 1992, p. 39-40).

Temple Grandin wrote : « Minor sensory processing deficits heightened my attraction to certain stimulation (e.g. airport's doors), whereas a greater sensory processing defect might cause another child to fear and avoid the same stimulus. Some of the problems autistics have with making eye contact may be nothing more than an intolerance for the movement of the other person's eyes. One autistic person reported that looking at people's eyes was difficult because the eyes did not stay still (...) Distorted visual images may possibly explain why some children with autism favor peripheral vision. They may receive more reliable information when they look out of

the corners of their eyes. One autistic person reported that he saw better from the side and that he didn't see things if he looked straight at them (...)" (Grandin, 1995, p. 73-75).

These self-reports gave us clear guidelines for our investigation of visual-motion processing impairments in ASD.

(5) Experimental cognitive neuropsychology.

Autism spectrum disorders (ASD) are known as neurodevelopmental disorders marked by social interaction and verbal and non verbal communication impairments. Since human faces are the primary and most powerful source of information mediating emotional and verbal communication as well as social interaction, it is not surprising that face processing has often and regularly been studied in autistic population for the past thirty years. Indeed, a growing body of data has been showing that subjects with ASD generally process various aspects of faces differently than normal subjects do. An important question was to know whether each aspect of face processing is impaired separately, or based on one or more general and basic impairment concerning environment processing and affecting all these various aspects.

Two previous studies conducted by our group, concerning with various aspects of face processing (identity, expressions of emotion, eye direction detection and lip-reading) in young children and adolescents with autism, revealed that the aspects of faces which were the most difficult to process were specifically related to facial configuration, visuo-auditory association, and facial dynamics, i.e., lips' movements, eyes' movements and emotional facial expressions, (Gepner et al., 1994 ; Gepner et al., 1996). These last results suggested that difficulties of children with autism in processing faces were neither related to impairments in recognition of facial identity *per se*, nor to impairments in recognizing emotional aspects of faces *per se*, but rather to specific anomalies in the processing of facial movements.

As Milne et al. said, we showed more recently that children with autism also have a difficulty to use low spatial frequency information when processing faces (Deruelle et al., 2004), a result confirming that autistic children have spatial information processing disorders.

III- Previous and recent works on physical and biological motion processing

All these arguments pushed us to investigate directly how subjects with ASD process visual movements, physical movements as well as biological ones.

(1) Physical movements processing

As Milne et al. (2005) said, our group was the first, ten years ago, to assess directly visual-motion processing in children with ASD. We first established that children with autism exhibit a poor postural reactivity to visually perceived environmental movements (Gepner, Mestre, Masson and de Schonen, 1995).

Then we replicated this study, and showed that children with autism were particularly impaired in postural reactivity when *speed of movement* was high (slow movements inducing a small postural reactivity), whereas children with Asperger syndrome were reacting normally, and even maybe overreacting, to the same kind of stimuli. In other terms, visuo-postural coupling is deficient in children with autism, and conversely, children with Asperger rather show a visuo-postural hyper-coupling. Thus, visuo-postural coupling (and more generally, sensorimotor coupling) may be a good neuropsychological marker of autism, and possibly a good predictor of the severity of ASD (Gepner and Mestre, 2002a).

We were then surprised that in their review Milne et al. (2005) did not take into account the question of *speed of movement* raised by Gepner and Mestre (2002a)'s study.

Indeed, speed of movement seems to be critical for children with ASD : Gepner (1997) showed that children with autism were also impaired in the perception of moving singular points in central vision, and that their performance was all the less so as speed of moving points was high and direction was complex (i.e., less foreseeable).

As far as direction of movement is concerned, Bertone et al. (2003) also showed that high-functioning subjects with autism exhibited second order radial, translational and rotational direction of movement deficit.

Other works by Spencer et al. (2000) and Milne et al. (2002) showed that children with autism had higher motion coherence thresholds than normal control children. Mestre et al. (2002), using the same motion coherence paradigm but with video-oculographic measure of OKN, showed that motion coherence thresholds in children with autism were particularly different from that of normal control children when speed of motion was high, thus confirming visual-motion processing deficit in autism, especially for high speed of movement. A reasonable interpretation of this result is a lack of integration of singular points in a global coherent motion (a form of central coherence deficiency), which is also confirmed by Pellicano et al, (2005).

Interesting finding on pursuit eye movements deficits in HFA children (Takarae et al., 2004) is also to be reported, that suggests a disturbance in the extrastriate areas that extract motion information, or in the transfer of visual motion information to the sensorimotor areas that transform visual information into appropriate oculomotor commands. However, another group did not find smooth pursuit eye movements deficits in children with pervasive developmental disorders (Kemner et al., 2004).

(2) Biological motion processing

Milne et al. (2005) forgot to report that our group was also the first to introduce a new paradigm, *facial motion*, in order to further investigate and analyze results on facial recognition in autism. Indeed, we showed that children with autism, comparatively to normally developing children (of the same developmental age), had relatively good performance in emotional and non emotional facial recognition tasks when facial expressions were displayed slowly on video (Gepner, Deruelle and Grynfeldt, 2001). We thus argued that children with ASD were impaired in rapid facial movements processing, and that this impairment could explain gaze avoidance and poor performance in emotional and nonemotional facial processing in these children (Gepner, 2004).

Blake et al. (2003) showed that children with autism were impaired in the recognition of human movements (e.g., walking, running or jumping) displayed through animated lighting points.

Finally, at the intersection of physical and biological motion processing, Castelli et al. (2002) showed in a TEP study, that adults with high-functioning autism or Asperger syndrome have a hypoactivation of median prefrontal cortex and superior temporal sulcus (STS) when they have to attribute mental states to animated shapes, and a diminution of connectivity between extrastriatal cortex and STS.

(3) First synthesis

All these studies confirm that subjects with ASD have visual-motion perception and integration disorders, whether physical or biological motion, that we have named previously *visual-motion mis-sight* in autism (Gepner, 2001).

In particular, Gepner and Mestre (2002b) reached the conclusion that children with autism have a rapid visual-motion integration deficit.

In order to integrate the various developmental consequences of this disorder, we now propose to name it *E-Motion mis-sight* (see Figure 1).

Figure 1 about here

Given i) the implication of the magnocellular pathway in processing visual motion, ii) the role of visual inputs, and especially the dynamic ones, for visuo-motor control through mossy fibres via the pontine nuclei to the cerebellum (Stein & Glickstein, 1992), iii) the role of cerebellum in integrating multisensory input, and especially its role in speed and temporal coding of these inputs (e.g. Johnson & Ebner, 2000), iv) its role in motor control through real-time fine-tuning of movement (e.g. Ito, 1984), and v) the co-contributing roles of cerebellum and basal ganglia for motor control as well as for learning (Doya, 2000), through their projections not only on the motor and premotor cortices but also on the prefrontal, temporal and parietal cortices (Middleton & Strick, 2000), we thus previously suggested (Gepner and Mestre, 2002a, 2002b) that visual magnocellular system, visuo-cerebellar pathways and cerebello-premotor-motor pathways might be centrally involved in the neurophysio-pathology of at least a subclass of autistic spectrum disorders, and could explain the strange visuo-motor reactivity, as well as the strange cognitive style and higher-order cognitive peculiarities observed in this population. The discovery of hypoplastic or hyperplastic cerebellar vermal lobules VI and VII involving Purkinje cells in autistic adults (Courchesne, 1997), which supposes hypo- and/or hyperconnectivity according to a neuromimetic model, gives a strong support to this suggestion. In the same line, it was found that a specific damage of the cerebellar vermal lobules VI and VII is responsible for a deficit in the accuracy of ocular saccades (Lewis and Zee, 1993), and thus may negatively impact visual motion integration. As Milne et al. (2005) also said, several neurofunctional systems and networks, including visual magnocellular system, dorsal stream and cerebellum, as well as superior temporal sulcus, which is involved in facial movements processing (Allison et al., 2000), are most probably involved in visual-motion processing deficits in autism and need to be further investigated.

IV- Other temporal processing disorders in autism

Even though *E-Motion mis-sight* may account for some of the major sensorymotor, behavioral and communicative disorders manifested by children with ASD, it is however unable to explain autistic symptoms occurring in other sensory modalities (e.g. auditory or proprioceptive). A crucial question coming next was thus to know whether this visual-motion integration deficit reflects, or results from, a more primary and pervasive neuropsychological deficit. A plausible candidate-deficit concerns with temporal processing within various sensory modalities.

(1) Is the world going too fast for persons with autism ?

In order to explore the effectiveness of a temporal processing deficit in autism, we tested, within a same group of children and adolescents with ASD, the ability to extract a relevant information among a noisy stimulus *on line*, through 3 types of tasks: a) oculomotor reactivity to visual-motion of a coherent pattern of lighting points through optokinetic nystagmus; b) speech flow perception and segmentation through categorization of simple and complex phonemes, and c) proprioception and motor anticipation in a bimanual load lifting task, through electromyographic and kinematic index. Results of this study were as follows.

As already mentioned above (see above Mestre et al., 2002), the group of subjects with ASD showed very weak oculomotor reactivity (i.e. a reduced occurrence of slow phase tracking eye movements) to visual motion of a coherent pattern, and higher motion coherence thresholds as compared to normal children of the same mean age, as already shown previously (Spencer et al., 2000 ; Milne et al., 2002). This deficit, which supposes a defect in rapid temporal analysis of visual motion stimuli embedded in noise, is a strong argument for a degraded temporo-spatial integration in the visual modality.

Secondly, the same group of autistic subjects showed a deficit in speech phoneme categorization. Indeed, compared to normal children who categorize an ambiguous phoneme such as MNA (made of an algorithmic superimposition of MA and NA) in a MA or a NA response randomly, autistic children over-categorize MNA in a NA response. This deviant over-categorization specifically appears in autistic subjects when speech phonemes are displayed at normal speed, whereas their phoneme category perception is normalized when phonemes are slowed down 2 times. This phoneme categorization deficit may partly be due to a difficulty in processing rapid speech flow, and thus to a temporal integration deficit in the auditory modality (Tardif et al., 2002). A similar temporal processing deficit exists in children with language-learning impairments (Tallal, 1976; Tallal et al., 1996), which has been related to a deficit in visual magnocellular system (Talcott et al., 2000) and/or auditory magnocellular system (Stein, 2001). Since superior temporal sulcus is involved not only in facial movement processing (Allison et al., 2000), but also in voice processing (Belin et al., 2000), and that it was found hypoactivated in adults with HFA in response to vocal sounds (Gervais et al., 2004), this region is also of strong interest in the pathophysiology of ASD.

Finally, it also appeared that a subgroup of the same autistic subjects present with deficit in motor anticipation in a bimanual load-lifting task (Schmitz et al., 2002), which confirms results of another study (Schmitz et al., 2003). This task requires the rapid processing of proprioceptive inputs, the correct use of an internal representation, and the precise timing adjustment of the muscular events. Compared to control children who use a feedforward mode of control to stabilize their forearm while lifting an object placed on it, autistic children mostly use a feedback mode of control, which results in slowing down their movement. In other words, autistic children are reacting instead of predicting. This deficit of accurate timing of anticipatory control could partly result from an impaired processing of proprioceptive inputs at least during the learning phase of the task, and thus from a temporo-spatial integration deficit in the proprioceptive modality.

According to these three series of results, subjects with ASD have deficiencies in the temporal processing of visual, auditory and proprioceptive stimuli *on line* (Gepner and Massion, 2002). Altogether, these results suggest that subjects with ASD have a deficit in the temporo-spatial processing of sensory inflow which is necessary to detect and integrate visual motion, code and parse language or program postural adjustments (see Figure 2). To summarize, *the world is changing too fast* for at least some autistic persons. This view could account for the sensory and social avoidance of autistic subjects (when sensory inflow is aversive), for the de-synchronization and discontinuity in their perception-action coupling and sensory-motor tuning, as well as for their mis-understanding of, and disorders in their action and interaction with, the physical and human world.

Figure 2 about here

(2) A recent study : Slowing down facial movements and sound flow enhances facial recognition and imitation in autistic children.

According to this temporal processing disorder hypothesis of autism, autistic persons present for more or less disabilities to integrate environmental world's sensory events *online*, and to produce real-time sensorymotor coupling and postural adjustments. Following this hypothesis and previous suggestions (Gepner and Mestre, 2002b), we explored in a recent study (Tardif, Lainé, Rodriguez and Gepner, submitted) whether slowing down simultaneously facial movements and their corresponding sounds would i) improve facial expression recognition and ii) induce facial and/or vocal imitation in children with autism, as already suggested previously (Gepner et al., 2001). In this study, children with mild or moderate-to-severe autism, and normal control children individually matched with the former on gender and either on verbal mental age or nonverbal mental age, were presented with a CD-Rom showing sixty-four randomly ordered 2-second sequences of emotional and nonemotional facial expressions, on a computer screen. Facial expressions were displayed under sounded or silent conditions, and under three dynamic visual conditions (*slow*, *very slow*, *normal speed*), plus a control static condition. Sounds were superimposed to facial movements, i.e., displayed slowly, very slowly or at normal speed.

Results of this study show that autistic children overall perform significantly more poorly than control children in all the facial expression recognition tasks, and in all the conditions. In autistic children, performance is proportional to mildness of autism. Autistic children perform significantly better in sounded than in silent conditions. They also perform better when facial expressions are slowed down than when displayed at normal speed or statically, a result observed only in children having moderate-to-severe autism. Furthermore, autistic children exhibit significantly more facial and vocal imitation than control children when exposed to stimuli. Besides, in autistic children vocal imitations are induced more frequently when facial expressions are sounded and slowed down. Conversely, no effect of slowing down on facial expression recognition and imitation is observed in control children. In summary, slowing down the speed of facial and vocal events enhances imitative and cognitive abilities of autistic children, especially in the most affected ones.

This finding strenghtens the temporal processing deficit hypothesis of autism (Gepner and Massion, 2002; Gepner, 2005). It is also the first evidence of the interest of slowing down the speed of visual and auditory environmental events around children with autism, and may be in the future a major key for rehabilitation of verbal and emotional communication of these children, particularly if applied early during their development (Tardif et al., submitted).

V- Conclusion : *E-Motion mis-sight* and other temporal processing disorders in autism

World is going too fast for at least some persons with autism, i.e., autistic persons present for more or less disabilities to integrate environmental world's sensory physical and biological events *online*, and to produce real-time sensorymotor coupling, as well as adequate verbal and nonverbal outputs : these disorders may be included into a synthetic neuropsychological approach, i.e., *E-Motion mis-sight and other temporal processing disorders*.

At a neurofunctional level, this approach may be accounted by the hypothetical *temporal binding deficit* in autism (Brock et al., 2002), i.e., a deficit in the synchronization of high frequency γ -activity between local networks, leading to the well accepted *central coherence deficiency* theory of autism (Frith, 1989; Happé, 1999). Interestingly, schizophrenic individuals show a reduced frequency of γ -oscillation when viewing a Gestalt (Spencer et al., 2004), i.e. a deficit in neural synchronization that would be responsible for impaired attentional, perceptive and/or cognitive acts in these patients.

According to our *E-Motion mis-sight and other temporal processing disorders* hypothesis of autism, we suppose here that a temporal dissynchronization within/between key neural networks, including especially visual and auditory magnocellular systems, cerebellum and

superior temporal sulcus, leading to dynamic disconnectivity (hypo- and/or hyper-connectivity) within/between these structures and numerous others, i.e. a *multi-system temporal dissynchronization and functional disconnectivity*, may be a crucial neuropsychological mechanism of autism.

According to the results of Tardif et al. (submitted), slowing down facial movements and corresponding sound flow simultaneously may act on temporal processing like a (re)-synchronizing factor thus facilitating perceptual and cognitive integration. Alternatively, slowing down sensory events would increase time for signal processing, thus also enhancing perception and cognition in autism.

Anyhow, visual-motion and sound flow are too rapid for some autistic persons to process and integrate, and this finding has two main consequences : first, it may serve in the future as early neuropsychological marker in the detection of babies and young children with ASD; secondly, it should logically induce clinicians, researchers and care-takers to slow down environmental world around this population, by ecological and artificial means.

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